technical note

AD-A214 577

DTIC FILE COPY

ILS Mathematical Modeling Study of the Effects of Proposed Hangar Construction at the Orlando International Airport, Runway 17R, Orlando, Florida

James D. Rambone
John E. Walls

September 1989

DOT/FAA/CT-TN89/52

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

NOTICE

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-TN89/52	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle ILS MATHEMATICAL MODELING STUDY OF THE EFFECTS OF PROPOSED HANGAR CONSTRUCTION AT THE ORLANDO INTERNATIONAL AIRPORT RUNWAY, 17R, ORLANDO, FLORIDA		5. Report Date September 1989 6. Performing Organization Code ACD-330
7. Author(s) James D. Rambone and John E. Walls		8. Performing Organization Report No. DOT/FAA/CT-TN89/52
9. Performing Organization Name and Address Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, N.J. 08405		10. Work Unit No. (TRAIS) 11. Contract or Grant No. T0605A
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Maintenance and Development Service Washington, D.C. 20590		13. Type of Report and Period Covered Technical Note August 1989 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This Technical Note describes the instrument landing system (ILS) math modeling performed by the Federal Aviation Administration (FAA) Technical Center at the request of the Southern Region. Computed localizer data are presented showing the effects of two hangar buildings (Braniff and Comair) on the performance of an ILS localizer proposed for runway 17R at the Orlando International Airport. The Southern Region is concerned that radio frequency (RF) signal reflections from the two hangars may degrade the localizer course beyond Category II/III tolerances. Modeled course structure results indicate that Category II/III localizer performance should be obtained with the Wilcox Mark II, 14-element, dual-frequency log periodic antenna with both hangar buildings constructed at the currently proposed locations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.

Data are also presented showing the computed performance for a glide slope proposed for runway 17R at the Orlando International Airport. The null reference glide slope will be located 1050 feet back from runway threshold and 400 feet left offset of centerline. Glide slope modeling computed only the effect of terrain in front of the antenna system and was conducted with the GTD-2D model because of limited terrain data availability. Modeled path structure and level run plots are provided for the proposed null reference system. Modeled results indicate that the proposed site should meet Category II path structure, linearity, and symmetry tolerances.

17. Key Words Instrument Landing System Math Modeling ILS Localizer, ILS Glide Slope ILS/Orlando, FL Orlando, FL/ILS	18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 22	22. Price

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

EXECUTIVE SUMMARY

This instrument landing system (ILS) math modeling study was performed at the request of the Southern Region to compute the effects of proposed hangar buildings on the performance of an ILS localizer proposed for runway 17R which is under construction at the Orlando International Airport. Reflections from other structures on the airport are not considered in this localizer modeling study. The localizer was modeled using a physical optics mathematical model developed by the Transportation Systems Center. As requested by ASO-433, a Wilcox Mark II, 14-element, dual frequency log periodic antenna array was modeled. Derogative effects from two hangar buildings (Braniff and Comair) were considered. Modeled course structure results indicate that Category II/III localizer performance should be obtained for runway 17R with the hangars constructed at the currently proposed locations. Computed clearance orbit results indicate satisfactory linearity, course crossover, and signal clearance levels.

The Southern Region also requested modeling of a null reference glide slope proposed for runway 17R at the Orlando International Airport. The null reference glide slope will be located 1050 feet back from runway threshold and 400 feet left offset of centerline. Glide slope modeling computed only the effect of terrain in front of the antenna system and was conducted with the GTD-2D model because of limited terrain data availability. Modeled path structure and level run plots are provided for the proposed null reference system. Modeled results indicate that the proposed site should meet Category II path structure, linearity, and symmetry tolerances.

INTRODUCTION

PURPOSE.

The purpose of this math modeling study was to provide computer modeled performance data for an instrument landing system (ILS) localizer and glide slope proposed for runway 17R at the Orlando International Airport.

BACKGROUND.

The Southern Region will be installing an ILS localizer and glide slope to serve runway 17R which is under construction at the Orlando International Airport. In support of this project, ASO-433 has requested a math modeling study through the Navigation and Landing Division, APS-400, which, in turn, was forwarded to the Federal Aviation Administration (FAA) Technical Center for accomplishment. ASO-433 requested modeling of two hangar buildings (Braniff and Comair) proposed for construction near the northeast end of runway 17R for their effect on a Wilcox Mark II, 14-element, dual frequency log periodic dipole (LPD) antenna proposed for runway 17R. Category II/III localizer performance is required. Glide slope math modeling was also requested for a null reference system proposed to serve runway 17R to provide Category II performance. The proposed site is located 1,050 feet backset from threshold and 400 feet left offset of centerline.

Glide slope math models currently available at the Technical Center are designed to model the effects of terrain on system performance. The effects of structures are not considered. Therefore, glide slope modeling was limited to the derogating effects from a planned taxiway and the terrain immediately in front of the proposed site.

This modeling effort was performed under project T0605A. The Technical Program Manager is Mr. Edmund A. Zyzys. Additional information regarding this study may be obtained by contacting Messrs. James D. Rambone or John E. Walls at FTS 482-4572 or (609) 484-4572.

DISCUSSION

ILS MATH MODELS.

The FAA Technical Center conducts ILS mathematical computer model studies through application of physical optics or geometric theory of diffraction techniques to compute anticipated ILS performance. The modeling for the runway 17R localizer was performed using the physical optics localizer model developed by the Transportation Systems Center (TSC) and converted to the Technical Center's mainframe computer. References 1 through 3 describe the modeling technique and implementation. Reference 4 provides validation data for the localizer model.

Figure 1 illustrates the right-handed coordinate system used in this computer model with the origin located at the threshold of the runway. The positive x-axis is directed out from the threshold along runway centerline extended, the positive y-axis is directed to the left, the positive z-axis is directed up.

Alpha, the angle between the base of a reflector and the x-axis, is measured in the counterclockwise direction. Delta is the angle between the surface of the reflector and the vertical direction. The large solid arrows in the figure point in the direction that the reflecting surface faces. A reflector facing in the negative y-direction has an alpha of 0^{o}. A reflector with a delta of 0^{o} is perpendicular to the ground (see A in figure 1). Delta is equal to -90^{o} for a horizontal reflector facing down (see B in figure 1). An alpha of 90^{o}, as shown in C in figure 1, faces the reflector out along the positive x-axis. A surface illuminated by radio frequency (RF) energy from the antenna is modeled by a rectangular flat surface or cylindrical surface. This surface is considered to be of infinite conductivity over the total surface and to have zero thickness. This assumption will result in a worst case performance prediction. The model does not compute multiple reflections or diffractions. Course deviation indicator (CDI) deflections are computed as follows. First, the magnitude and phase of the RF signals arriving at the aircraft location are determined for each surface independently. Next, a resultant RF signal is computed by vectorially combining the independent signals. CDI deflection is then computed from the resultant RF signal.

The mathematical model used for the glide slope simulation was the Ohio University Geometrical Theory of Diffraction (OUGTD) model which was obtained from Ohio University under an FAA Technical Center contract. This program was written for Ohio University by Mr. Vichate Ungvichian to account for the interactions of electromagnetic waves when reflected and/or diffracted from the terrain between an ILS antenna and an aircraft (reference 5). The OUGTD program utilizes the Geometrical Theory of Diffraction (GTD) and the Uniform Theory of Diffraction (UTD) as the basic theories when computing the diffraction of the electromagnetic waves. The GTD and UTD theories both treat electromagnetic waves as rays. This is acceptable due to the localized nature of wave interactions at very high frequencies (above 100 megahertz (mHz)). This treatment allows one to include the multiple interaction (i.e., doubly diffracted, etc.) between neighboring ground plates with little computational effort; this is a very difficult task when using the Physical Optics theory. The UTD theory is used to calculate the fields in the transition areas; the GTD theory is used in all other areas.

The model considers the direct ray plus 13 additional rays. Each ray is determined by the various terrain irregularities encountered in front of the ILS antenna system. These rays are:

1. Direct
2. Reflected
3. Diffracted
4. Reflected-reflected
5. Reflected-diffracted
6. Diffracted-reflected
7. Diffracted-diffracted
8. Reflected-reflected-diffracted
9. Reflected-reflected-reflected
10. Reflected-diffracted-reflected
11. Diffracted-diffracted-reflected
12. Reflected-diffracted-diffracted
13. Diffracted-reflected-reflected
14. Diffracted-reflected-diffracted

The 2-D version of the model was used for this modeling effort. This is an early version of the model which uses a single terrain profile to represent the terrain for all computations. This version was subsequently modified to better represent the terrain in front of the antenna system. The improved version, the pseudo 3-D model, uses a matrix of X, Y, and Z coordinates for the terrain to compute a new terrain profile for each observation point (simulated aircraft position). Input

data to the 2-D model consists of a single file which contains a matrix describing the terrain profile: X (distance perpendicular to the runway), Y (distance along the runway centerline extended), and Z (elevation values referenced to the base of the antenna mast). The file also contains antenna system parameters (location, amplitude, and phase of each antenna element), along with other pertinent site and flightpath data.

Antenna heights were computed to produce actual path angles of approximately 3.0°. Antenna current phasing for all simulations were computed using a simulation of the airborne phasing techniques detailed in the Flight Inspection Manual OAP 8200.1 (reference 6). In the simulation, samples of antenna current phase are recorded while flying the simulated aircraft along an approach angle of 1.5° from 8 to 4 nautical miles (nmi) with respect to the site. Ten samples of antenna current phase are recorded for each antenna. Using average phase values, the phase of the upper antenna is adjusted for zero phase difference with respect to the lower antenna for sideband reference or null reference systems. For the capture effect system, the phases of the lower and upper antennas are adjusted to result in zero phase difference with respect to the middle antenna. This technique is similar to the method originated by the Ohio University Avionics Center for their modeling applications.

ILS MODELING PERFORMED.

Figure 2 shows the general orientation of the runway. The TSC localizer model was used to model the effects of the Braniff and Comair hangars wall and roof surfaces. As requested, the Wilcox Mark II, 14-element, dual frequency LPD antenna was modeled at the proposed ILS localizer site. Table 1 summarizes the localizer model input data. Antenna currents and phases used for the antenna array are also given in table 1.

Localizer course structure and clearance orbit computer runs were made for the hangar configuration shown in figure 3. The location and dimensions of all reflecting surfaces are detailed in table 2. Rectangular plates were used to simulate all of the reflecting surfaces. The Comair hangar was modeled using plates representing surfaces A, B, C, and D. Plate A represents the wall surface which is perpendicular to runway 17R. Plate B represents the wall surface which is 4° short of being perpendicular, and plate C is the wall surface that is parallel. Plate D represents the slanted roof of the Comair hangar which is 57 feet high and 132 feet long. The base height of this plate is 40 feet above ground level. Plates E, F, and G were used to represent the surfaces of the Braniff hangar which would be illuminated by localizer signals. Plate E represents the perpendicular wall surface of the hangar, while plate F is the parallel wall surface. The slanted roof of the Braniff hangar is represented by plate G, which is 116 feet high and 350 feet long. This plate is at a base height of 64 feet above ground level.

The GTD-2D glide slope model was used to model the effects of terrain because available terrain data was limited to a single elevation contour parallel to the runway extending from the glide slope site toward the middle marker (figure 4). As requested, a null reference antenna was modeled at the proposed glide slope site. A summary of the model input data describing the null reference antenna system at the proposed site is provided in table 3. Glide slope level and path structure computer runs were made with this data.

TABLE 1. LOCALIZER ANTENNA MODEL INPUT DATA SUMMARY

Localizer Antenna Type:	Wilcox Mark II, LPD 14-Element, Dual Frequency
Runway 17R Length (ft):	10000.0
Distance to Runway 35L End:	1050.0
Frequency (MHz) - Not yet assigned:	110.0
Site Elevation (ft m.s.l.):	78.0
Course Width (deg):	3.63

14-Element LPD Array

Ant. No.	Spacing (wave length)	Carrier+Sideband Amplitude	Carrier+Sideband Phase (deg)	Sideband Only Amplitude	Sideband Only Phase (deg)
7L	-4.80	0.160	0	0.367	0
6L	-4.05	0.160	0	0.555	0
5L	-3.30	0.491	0	0.889	0
4L	-2.55	0.491	0	1.000	0
3L	-1.80	0.714	0	1.000	0
2L	-1.05	1.000	0	0.667	0
1L	-0.30	0.893	0	0.222	0
1R	0.30	0.893	0	0.222	180
2R	1.05	1.000	0	0.667	180
3R	1.80	0.714	0	1.000	180
4R	2.55	0.491	0	1.000	180
5R	3.30	0.491	0	0.889	180
6R	4.05	0.160	0	0.555	180
7R	4.80	0.160	0	0.367	180

Clearance Signals

Ant. No.	Spacing (wave length)	Carrier+Sideband Amplitude	Carrier+Sideband Phase (deg)	Sideband Only Amplitude	Sideband Only Phase (deg)
3L	-1.80	0.200	0	0.139	0
2L	-1.05	0.000	0	0.333	0
1L	-0.30	1.000	0	1.000	0
1R	0.30	1.000	0	1.000	180
2R	1.05	0.000	0	0.333	180
3R	1.80	0.200	0	0.139	180

ft - feet
MHz - megahertz
m.s.l. - mean sea level
deg - degree

TABLE 2. LOCALIZER REFLECTING SURFACES DATA SUMMARY

Surface	Coordinates X*	(ft) Y*	Z**	Alpha (deg)	Delta (deg)	Width (ft)	Height (ft)
A	396	-1670	12	270.0	0.0	63	15
B	390	-1568	12	266.0	0.0	132	28
C	450	-1512	12	180.0	0.0	122	32
D	390	-1568	40	266.0	86.0	132	57
E	953	-1749	12	270.0	0.0	350	52
F	1140	-1577	12	180.0	0.0	364	72
G	1005	-1749	64	270.0	80.0	350	116

* - Midpoint of base of surface referenced to threshold of runway 17R.

** - Referenced to base of antenna.

TABLE 3. GLIDE SLOPE DATA SUMMARY

Null Reference Antenna	Height/Offset (ft/ft)
Lower Antenna	14.13/0.00
Upper Antenna	28.27/-0.75
Antenna	
Backset from threshold (ft)	1050.00
Offset from centerline (ft)	400.00
Elevation (ft m.s.l.)	87.00
Average Path Angle (deg)	3.00
Path Width (deg)	0.70
Path Symmetry (percent)	47.0/53.0
A-Ratio*	0.312
Phase (deg)	-10.12

* A-Ratio - Ratio of separate sideband signal amplitude to carrier sideband signal amplitude.

DATA PRESENTATION.

Modeled output results for the localizer are provided on three types of plots: (1) course structure plots, (2) clearance orbit plots, and (3) carrier plus sideband (CSB) and sideband only (SBO) antenna pattern plots. The simulated flightpaths for the course structure runs are centerline approaches starting 60,000 feet from runway threshold. The aircraft crosses the runway threshold at the threshold crossing height and continues at this altitude to a point just short of the stop end of the runway. Distances shown on the horizontal axis of the course structure plots are referenced to the approach threshold. Negative values are shown for distances between the threshold and the localizer. Positive values apply to distances on the approach path toward the outer marker. Angular values on the horizontal axes of the CSB and SBO antenna pattern plots and on the clearance orbit plots were run with flight arcs of 35,000 feet at altitudes of 1,000 feet with respect to the localizer site.

The vertical axes of the course structure and clearance orbit plots are the model output values of CDI deflection in microamps (0.4-second time constant applied for smoothing). The vertical axes of the antenna pattern plots use a relative scale with the pattern normalized to its peak value. The usual range for the vertical scale of modeled course structure data plots is +40 to -40 microamps. This range has been reduced to +10 to -10 microamps for the course structure plots provided in this study in order to better display small values of CDI deflection. This choice of scale eliminates the display of category I limits from the plot and shows only the final segment of the Category II tolerance limits. Category III tolerance limits (not shown) extend the 5-microamp tolerance shown for category II performance to a point on the runway 3,000 feet from threshold. The limits then increase linearly to 10 microamps at a point which is 2,000 feet from the stop end of the runway.

Modeled localizer computed performance data are provided in figures 5 through 7 with the Braniff and Comair hangar configuration as the only reflecting source. Modeled course structure is plotted in figure 5. Computed clearance orbit results are given in figure 6. Figure 7 shows the computed CSB and SBO antenna pattern plots.

Glide slope modeling results are presented in the form of course structure and level run plots. The reference flightpath for a structure plot is the hyperbolic path formed by the intersection of a cone originating at the base of the antenna and a vertical plane located along runway centerline. In the model, this path is determined by the location of the eyepiece of the theodolite. For the data presented, the theodolite eyepiece is positioned at the X and Y coordinates of the glide slope antenna mast, but at the elevation (Z coordinate) of the runway point of intercept (RPI). Modeled results are given in figures 8 and 9. Figure 8 is the modeled path structure run result for the null reference system installed at the proposed site. Figure 9 is the modeled level run result at the same location.

DATA ANALYSIS.

Localizer modeled course structure results for the Braniff and Comair hangars reflecting source configuration (figure 5) show computed CDI deflections that are well within Category II/III course structure tolerance limits. The computed clearance orbit plot (figure 6) indicates satisfactory linearity, course

crossover, and clearance levels. Figure 7, CSB and SBO antenna patterns for the Mark II antenna array, show some roughness in the computed clearance signals on the 90 hertz (Hz) side of the pattern.

Glide slope modeled path structure results (figure 8) indicate that the proposed site modeled provides a path structure well within category II tolerance limits. The level run results (figure 9) show a linear crossover and near symmetrical glidepath which meets Category II tolerances.

CONCLUSIONS

Localizer modeled results indicate that Category II/III localizer performance should be obtained with the Wilcox Mark II, 14-element, dual frequency log periodic dipole (LPD) antenna array with the Braniff and Comair hangars located as proposed. Computed clearance orbit results indicate satisfactory linearity, course crossover, and clearance levels. Glide slope modeled results using a single elevation contour profile also indicate that satisfactory Category II glide slope performance should be obtained with the null reference system installed at the proposed site. Level run performance meets Category II linearity and symmetry tolerances as well.

REFERENCES

1. Chin, G., et al., Instrument Landing System Scattering, Report DOT/FAA-RD-72-137, 1972.

2. Chin, G., et al., User's Manual for ILSLOC: Simulation for Derogation Effects on the Localizer Portion of the Instrument Landing System, Report DOT/FAA-RD-73-13, 1973.

3. Chin, G., et al., Instrument Landing System Performance Prediction, Report DOT/FAA-RD-73-200, 1974.

4. Chin, G., et al., ILS Localizer Performance Study, Part I, Dallas-Fort Worth Regional Airport and Model Validation, Syracuse Hancock Airport, Report DOT/FAA-RD-72-96, 1972.

5. User's Manual for the Ohio University Geometric Theory of Diffraction Glide Slope Model, Ohio University Technical Report Number OU/AEC/ERR 47-7, February 1982.

6. United States Flight Inspection Manual, FAA Handbook OAP 8200.1, Change 32, Section 217.

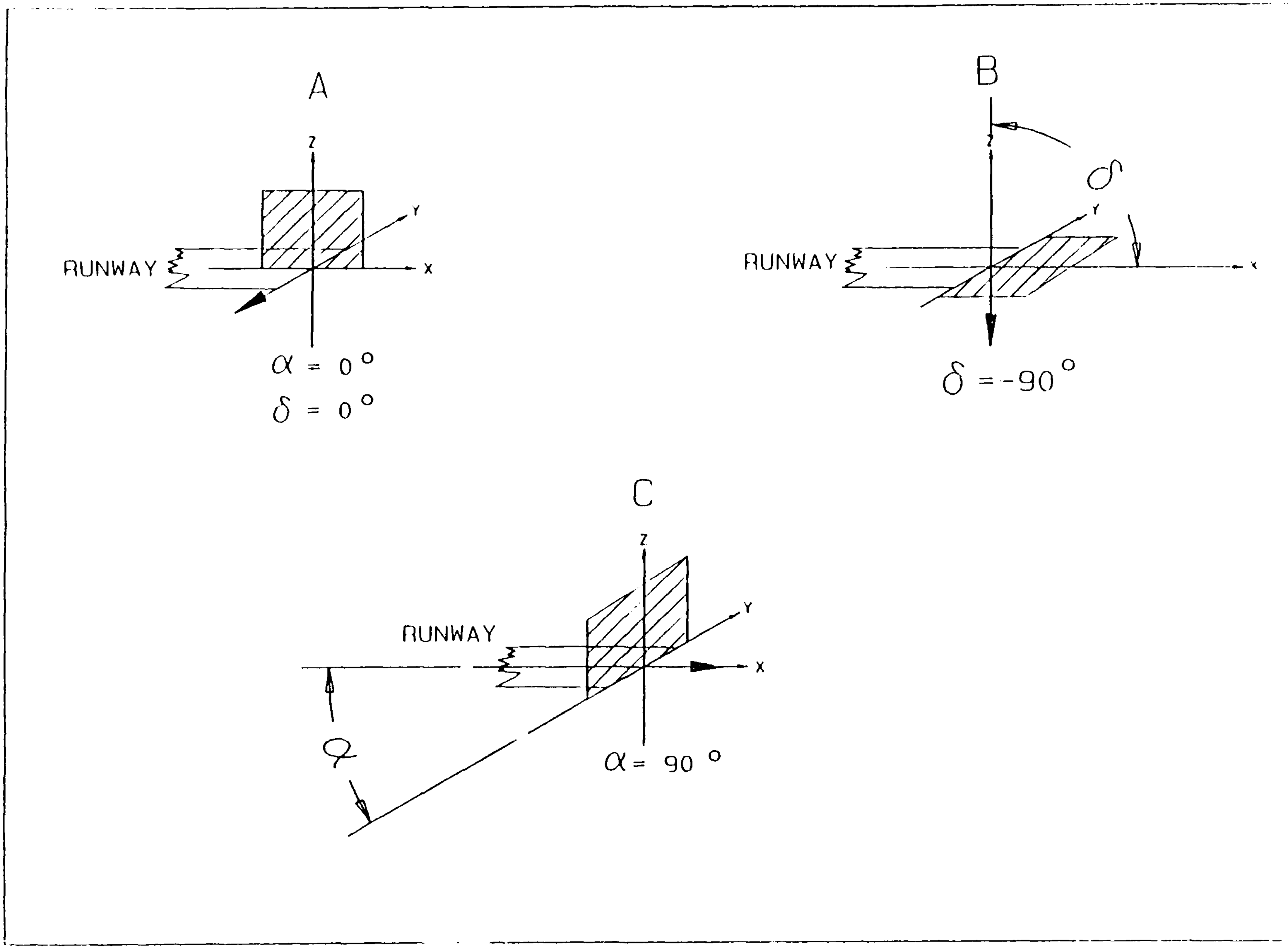

FIGURE 1. INSTRUMENT LANDING SYSTEM LOCALIZER MATH MODEL COORDINATE SYSTEM

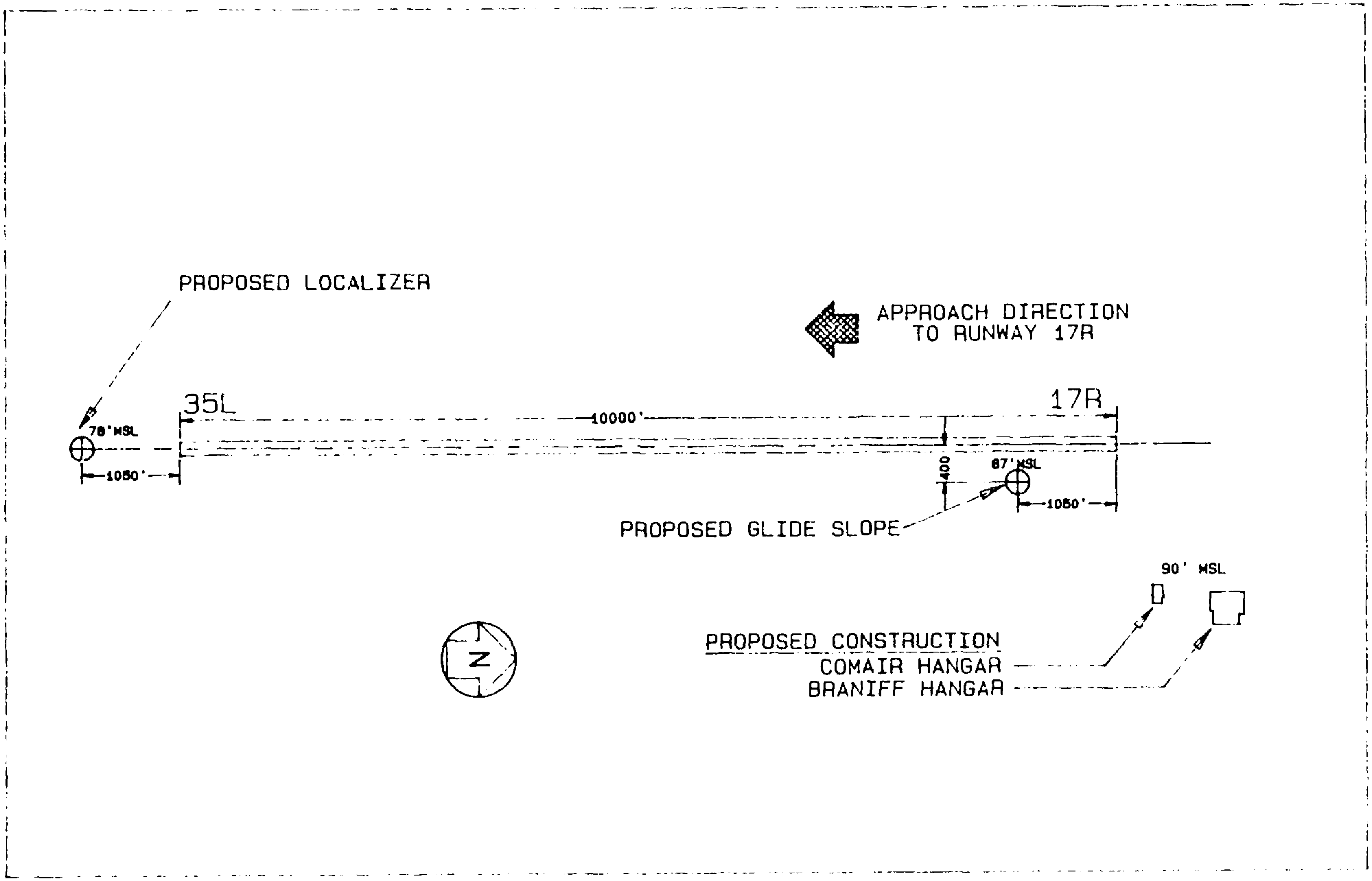

FIGURE 2. ORLANDO RUNWAY 17R, ILS MATH MODELING LAYOUT

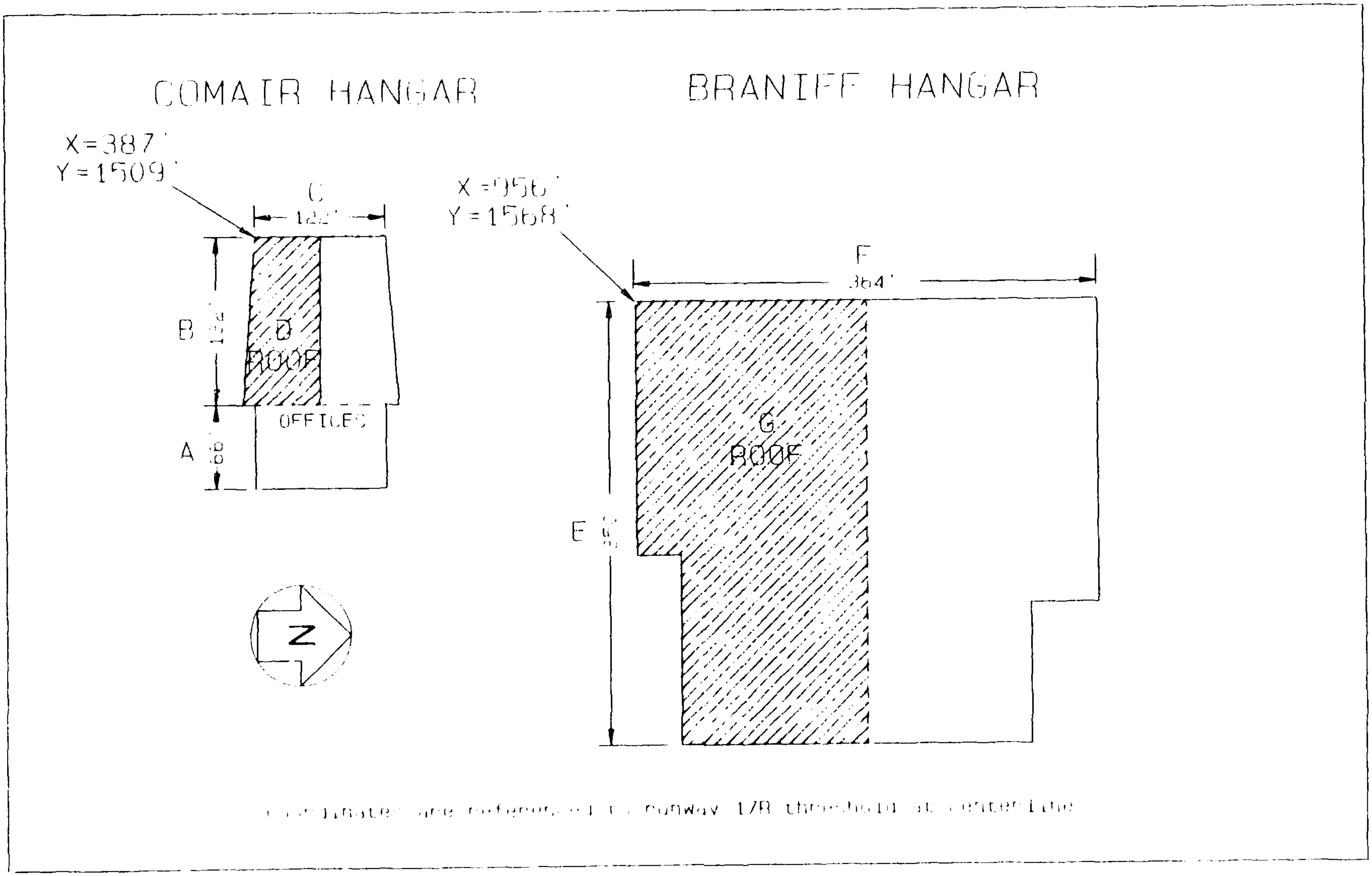

FIGURE 3. ORLANDO RUNWAY 17R, PROPOSED HANGARS SIGNAL REFLECTING SURFACE DETAILS

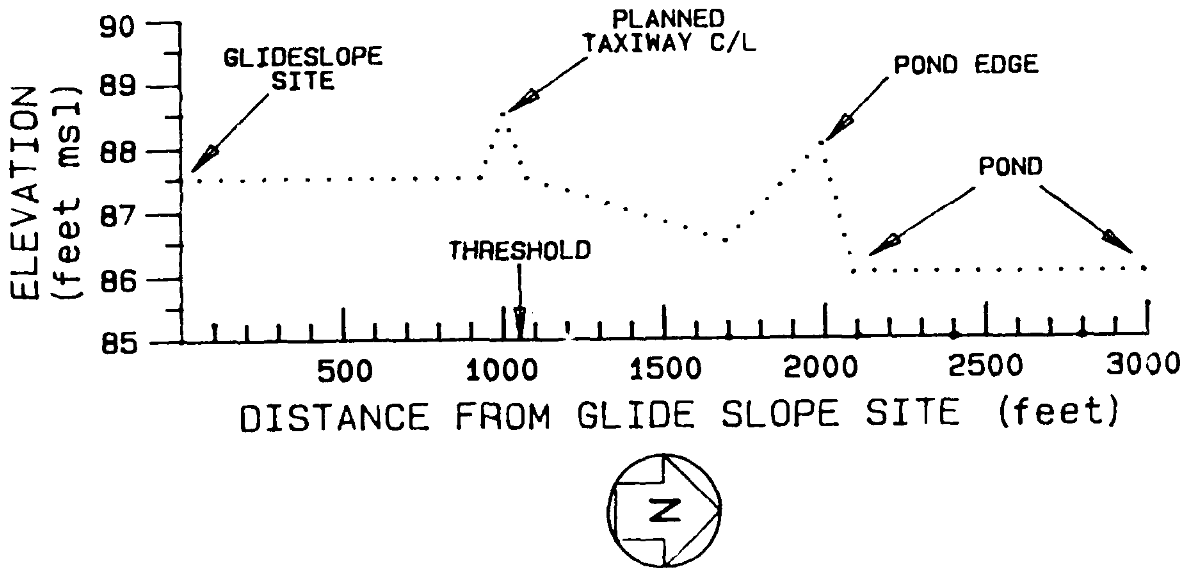

FIGURE 4. TERRAIN PROFILE IN FRONT OF THE RUNWAY 17R GLIDE SLOPE SITE

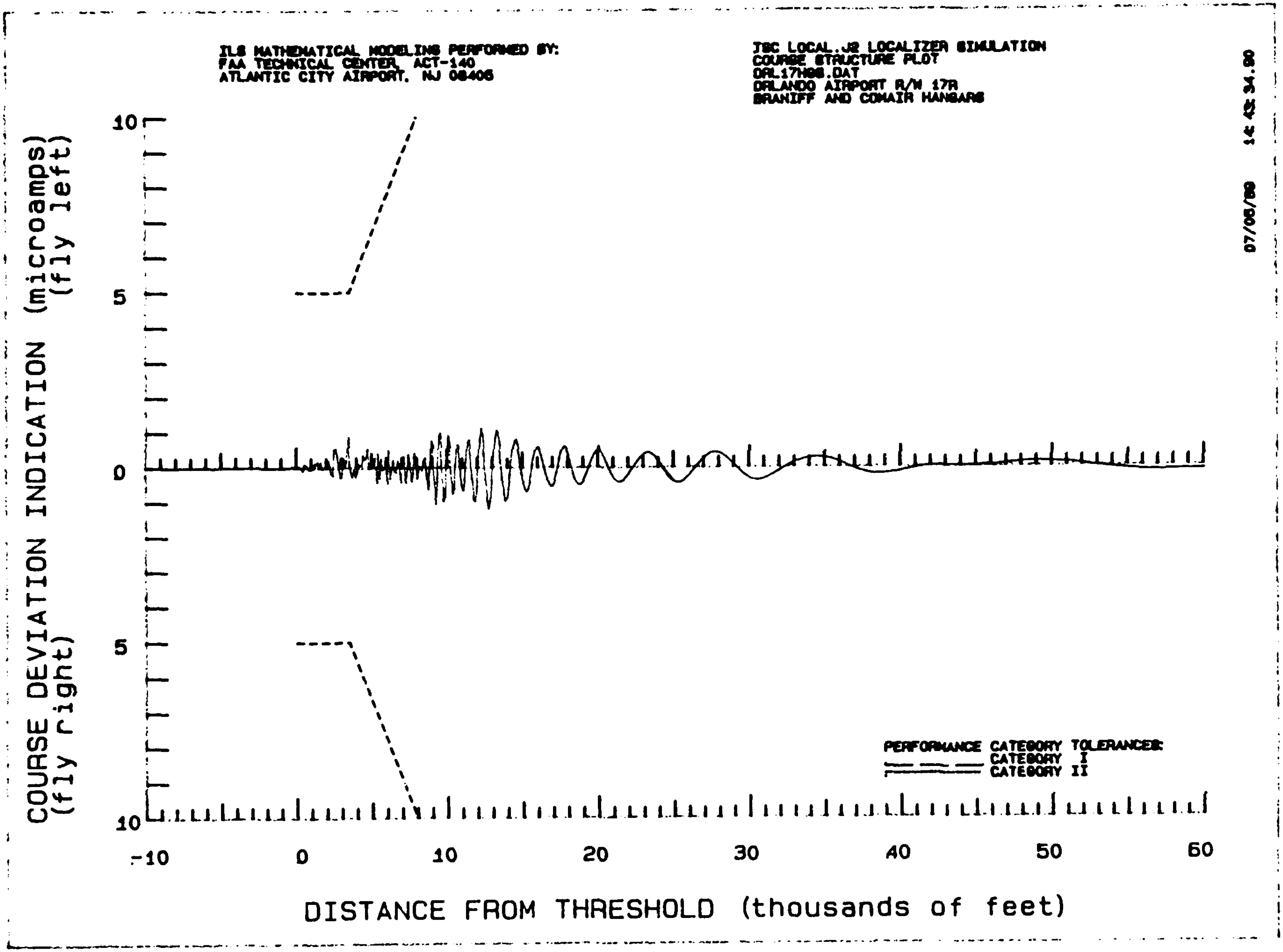

FIGURE 5. COURSE STRUCTURE, ORLANDO RUNWAY 17R LOCALIZER, BRANIFF AND COMAIR HANGARS

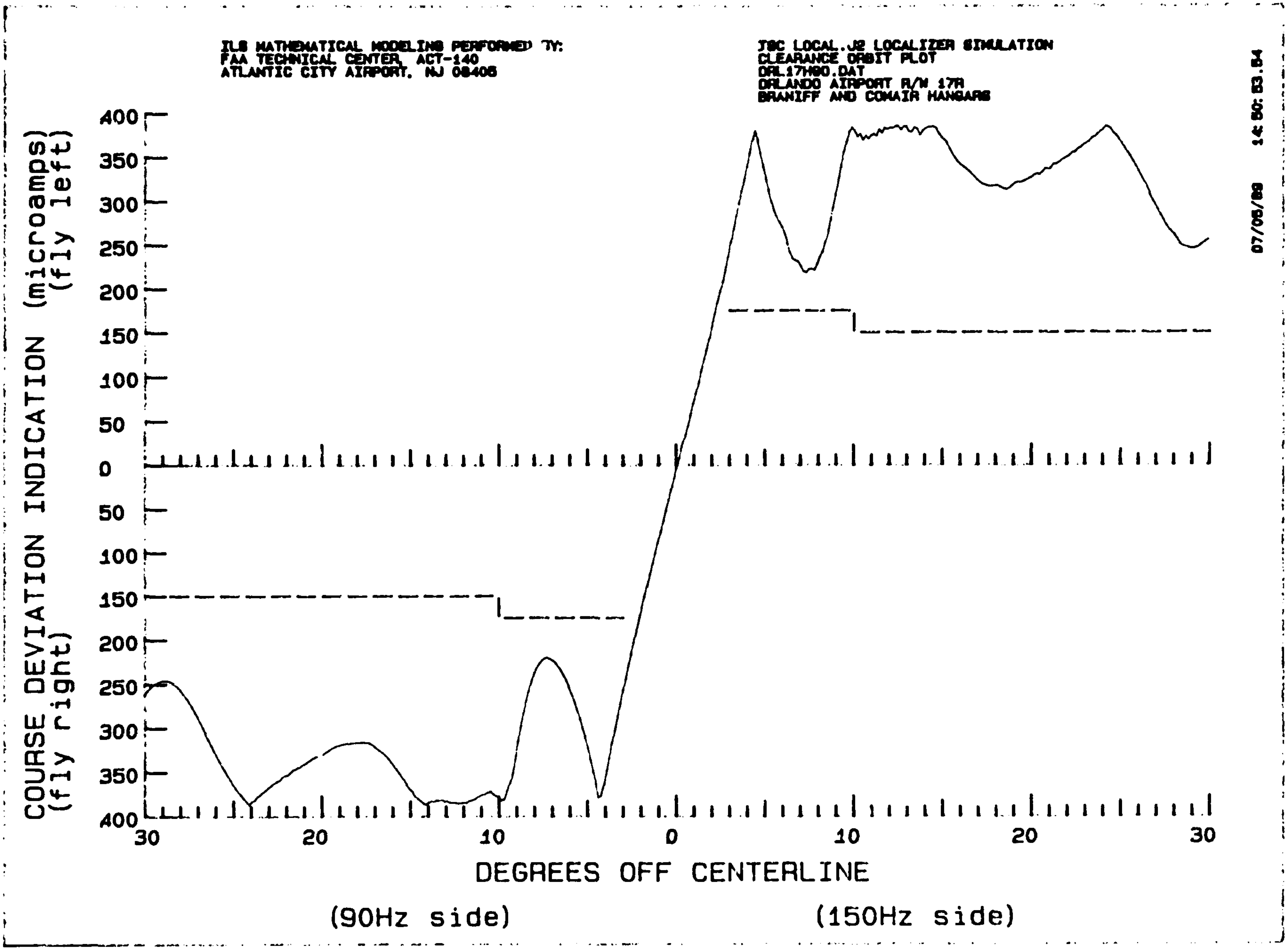

FIGURE 6. CLEARANCE ORBIT, ORLANDO RUNWAY 17R LOCALIZER, BRANIFF AND COMAIR HANGARS

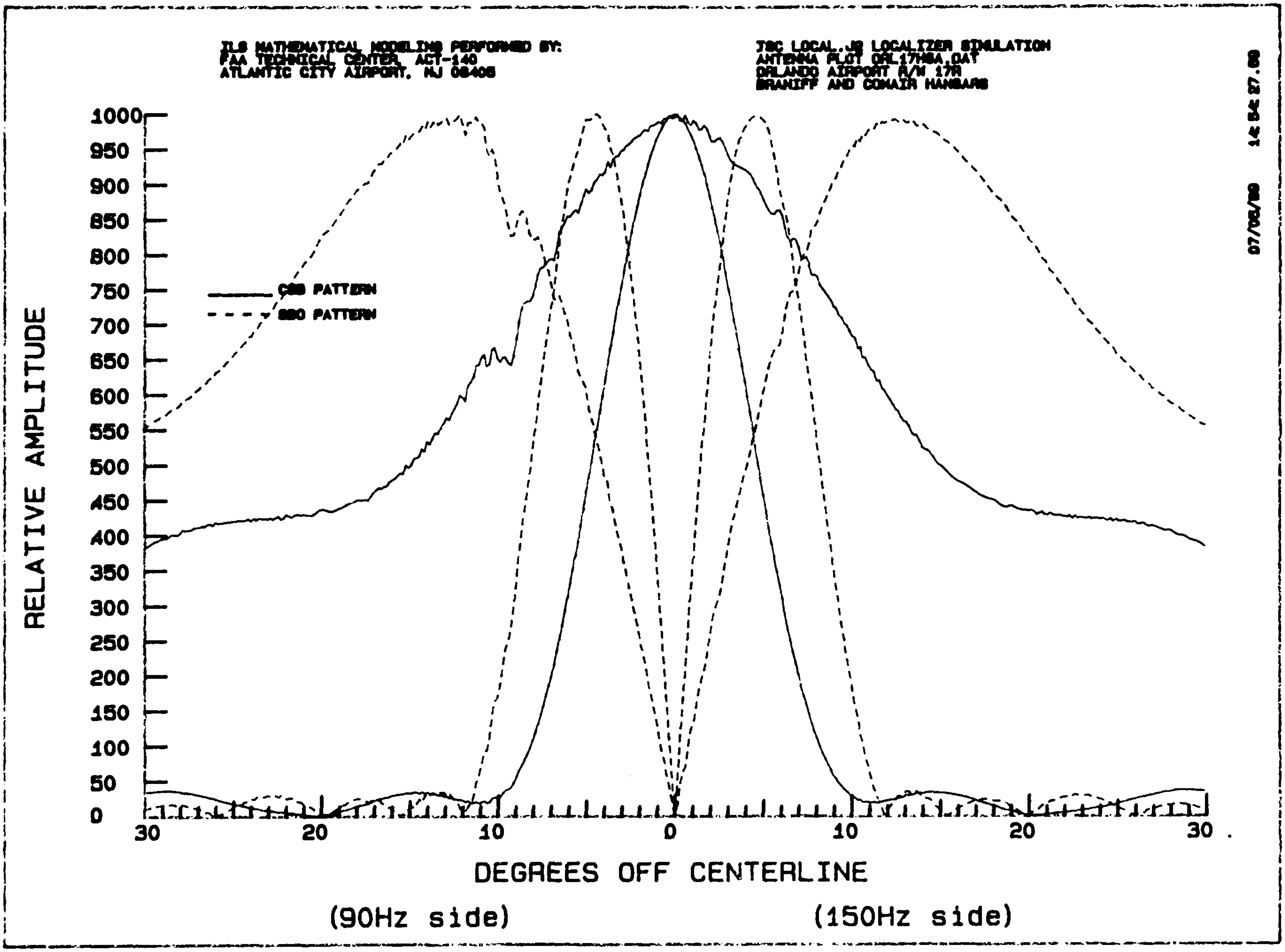

FIGURE 7. CSB AND SBO ANTENNA PATTERNS, ORLANDO RUNWAY 17R LOCALIZER, BRANIFF AND COMAIR HANGARS

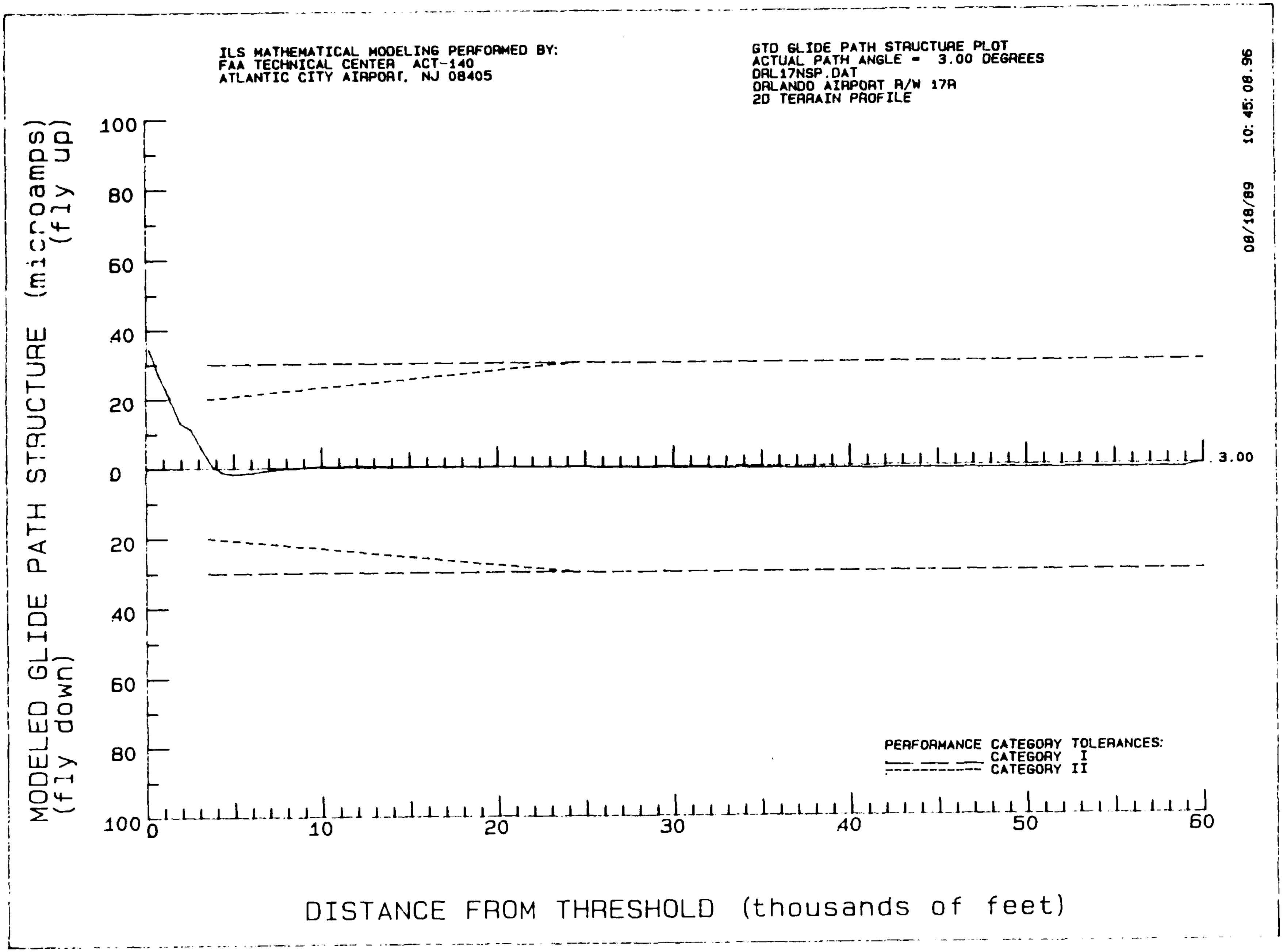

FIGURE 8. MODELED PATH STRUCTURE, ORLANDO RUNWAY 17R GLIDE SLOPE, NULL REFERENCE SYSTEM

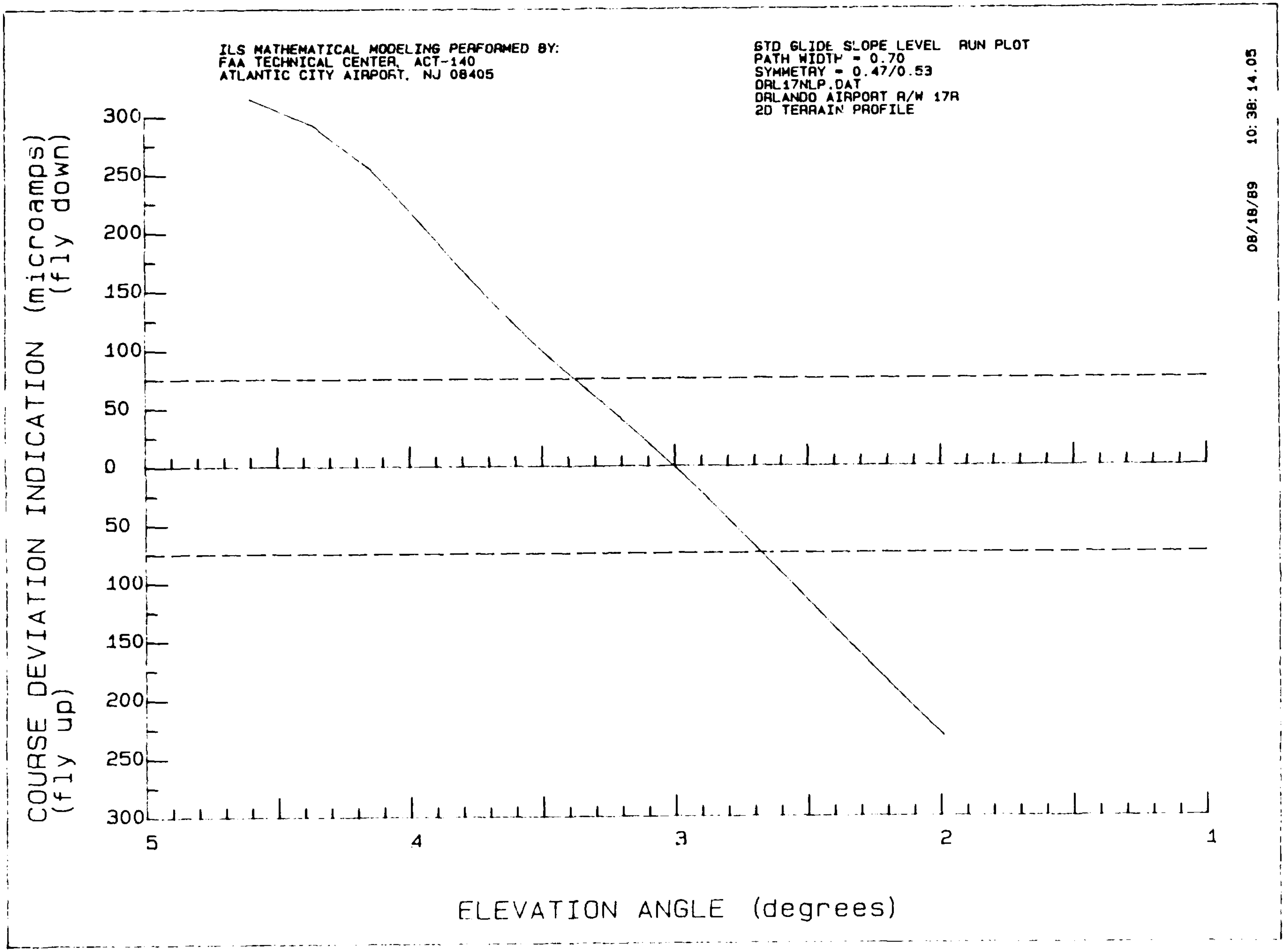

FIGURE 9. MODELED LEVEL RUN, ORLANDO RUNWAY 17R GLIDE SLOPE, NULL REFERENCE SYSTEM